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Implementing the Conservation Reserve Program: Analysis of Environmental Options. By Clayton W. Ogg, Marcel P. Aillery, and Marc O. Ribaudo, Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 618.

Abstract

Benefits would be mixed if the Conservation Reserve Program (CRP) were expanded to include irrigated land, highly erodible land, and cropped wetlands, which contribute to environmental problems. This report examines the following options for implementing environmental provisions of the CRP:

- Irrigated land. Enrollment costs for this acreage are high since irrigation is profitable in many areas. Net environmental benefits would not likely increase.

- Erodible land in watersheds with pollution problems. Water quality could benefit considerably by targeting selected watersheds. Targeting modest acreages of buffer strips near streams would increase benefits even more.

- Cropped wetlands. Wildlife habitat would improve by restoring up to 6 million acres to wetlands.

Keywords: Conservation Reserve Program, environmental pollution, ground water, water quality.

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Summary

Benefits would be mixed if the Conservation Reserve Program (CRP) were expanded to include more cropland that contributes to environmental problems.

This report considers five categories of land as options for implementing environmental provisions of the CRP: irrigated land on highly saline soils, irrigated land in ground water depletion areas, erodible land in watersheds with high sediment and nutrient pollution problems, buffer strips near streams, and cropped wetlands. Benefits and costs of enrolling these lands are compared with benefits and costs of enrolling highly erodible land already idled under the CRP.

- Irrigated land. Retiring irrigated farmland would result in significant environmental benefits per acre in improved water quality and ground water conservation. But program costs would be high because irrigated farming is profitable. Enrolling highly saline, irrigated soils would come at the cost of removing some of the Nation's most productive wheat acreage from production. Because irrigated cropland in ground water depletion areas is also highly productive, altering CRP eligibility rules to include these irrigated lands would raise the costs of the CRP.

- Erodible land in watersheds with pollution problems. Adding more acreage of currently eligible, erodible land to the CRP is one of the most effective means of reducing lake and stream pollution from sediment and nutrient runoff. This report identifies priority regions that could be targeted to gain maximum benefits.

  Setting aside a buffer strip of vegetation near streams could reduce water pollution even more, and at reasonable cost. This relatively small acreage offers an efficient tool for targeting water quality, primarily on fields with modest slopes which were largely unaffected by the CRP for highly erodible land. Environmental benefits from stream buffers can be significant per acre retired, provided they are well designed or applied in non-hilly areas. Opportunities to expand the CRP under the stream buffer provisions are limited, however, since only about 3 million acres are available for enrollment.

- Cropped wetlands. Cropped wetlands often can be restored to their natural wetland condition at lower cost. Some cropped wetland that suffers from inadequately treated wetness is among the least productive land for farming. Environmental benefits of converting untreated wetlands have not been quantified precisely, but this category of land ranks high as an environmental goal.

Glossary

Algae blooms--Growth of algae during a seasonal cycle.

Eutrophication--Process where nutrients reduce oxygen in water, producing a water environment that favors plant over animal life.

Kjeldahl nitrogen--Organic forms of nitrogen, readily available for algae growth.

Leaching--Removal of soluble chemicals from the action of liquid soaking into the ground.

Nonpoint-source contamination--Pollution from broad areas, rather than from concentrated points.

Osmotic effects--Tendency of a solution to diffuse through a substance until equally concentrated on both sides.

Percolation--Process of seeping or draining through a porous substance.

Saline soils--Containing an excess of dissolved mineral salts, including sodium, calcium, magnesium, and potassium.

Sodic soils--Undissolved, sodium salts in the soil.

Water table--The upper limit of the portion of the ground wholly saturated with water.

Watershed--Area drained by a connecting set of streams.

Implementing the Conservation Reserve Program

Analysis of Environmental Options

Clayton W. Ogg
Marcel P. Aillery
Marc O. Ribaudo*

Introduction

Agriculture's contribution to environmental pollution and depletion of natural resources is an issue of public concern. Agriculture has been mainly linked to water pollution that has no single, easily identifiable source (nonpoint-source pollution). Surface water can be contaminated through runoff of pesticides, fertilizers, sediment, and mineral salts. Ground water can be contaminated by soluble substances leaching through the soil, or depleted by heavy use of water for irrigation.

The Food Security Act of 1985 introduced a 40-45 million acre Conservation Reserve Program (CRP) to reduce soil erosion, support farm income, and address agriculturally induced environmental problems. Policymakers have responded to the public's pollution concerns by proposing more extensive pollution control provisions in the CRP (24, 26).1/ About 70 million acres now are eligible for the CRP (31). This report addresses which types of land to target in order to gain maximum environmental benefits from the CRP.

Environmental Benefits of Retiring Cropland

Taking land out of production reduces offsite costs (damage that appears somewhere other than the originating farm). Highly erodible soils enrolled in the CRP through 1987 yield environmental benefits of about $10 per acre per year (19). The benefits of idling the types of land studied in this report are compared with the benefits of idling land now enrolled in the reserve.

Croplands may be enrolled in the CRP to address environmental goals under current rules. The Secretary of Agriculture changed the eligibility criteria in 1988 to allow enrollment of narrow strips of land near streams in order to cut sediment and nutrient runoff into waterways. In early 1989, cropped wetlands and areas experiencing scour erosion became eligible for the CRP.

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1/ Underscored numbers in parentheses identify sources cited in the References section at the end of this report.

Another way to implement environmental goals in the CRP is through State water-quality programs. Some State or local conservation organizations subsidize enrollment of CRP land that has been linked to an identifiable environmental problem (18).

Costs of Retiring Cropland

To measure the cost of enrolling various types of land in the CRP, we calculated net dollar returns forgone by the farm sector per unit of reduced production.2/ Net returns represent cash receipts (including deficiency payments) less all cash and ownership production costs other than land and management. Production costs include machinery, labor (including owner-supplied), fertilizer, pesticides, water, long-term costs of depreciation on capital equipment, and other costs such as seed or transportation of the product from the field (11). For regions in which a single commodity predominates, costs to retire land in the region are based on that individual commodity. Elsewhere, a nationwide average of net dollar returns is used.

Costs of enrolling land contributing to environmental and natural resource problems are compared with the costs of enrolling highly erodible cropland already idled by the CRP. Cost differences have important budgetary implications. To protect the United States' competitiveness in world trade, it is also desirable to idle only the least profitable (and therefore, least costly) land so that the most productive acreage remains in production. Marginal acreage is also more likely to stay retired after contracts expire.

Irrigated Land With Salt Concentration

Irrigation contributes to salt pollution through salt-concentrating and salt-loading processes (13). If irrigated croplands in areas with saline soils were added to the CRP, areas downstream would benefit from improved water quality.

At the farm level, excessive soil salinity reduces cropland productivity. Salts in the root zone retard crop growth because plants cannot absorb the water and nutrients they need to develop. In addition to such osmotic effects, salinity produces other effects that impair normal plant growth (13).

Productivity losses depend on how tolerant the crop is to salt. Table 1 shows tolerances of selected crops to saline soil conditions. Cotton, sugar beets, wheat, and other small grains are relatively salt tolerant and may be grown under moderately saline conditions with little effect on yield. Soybeans and rice are less tolerant of soil salinity than grains. Corn, alfalfa, and potatoes are quite intolerant of salt and suffer significantly reduced yields under saline conditions.

Saline soil conditions also increase production costs. Operating costs rise because more water is needed for soil leaching to avoid salt buildup. More

---

2/ Net returns correspond roughly to actual private sector rents, but not to actual CRP bid costs or to official U.S. Department of Agriculture cost series. Farmers enrolling land in the CRP have submitted high bids. The high bids may reflect a requirement that both tenants and landowners be compensated for retiring land (27).

fertilizer may be required to compensate for reduced productivity. Additional costs may include investment in irrigation and drainage systems (17).

Salts dissolve in water and leach from irrigated soils. They collect in stream channels and ground water aquifers, damaging offsite agricultural, municipal, and industrial water uses. Salinity damages occurring downstream

Table 1--Salt tolerance of selected crops

Crop	Salinity level at which yield begins to decline 1/	Yield decrease per unit of increased salinity 2/	Salt tolerance rating 3/
	Mmhos/cm	Percent	Rating
Alfalfa	2.0	7	MS
Apricot	1.6	24	S
Barley (forage)	2.0	5	T
Bermudagrass	6.9	6	T
Blackberry	1.5	33	S
Cabbage	1.8	10	MS
Clover	1.5	12	MS
Corn (forage)	1.8	7	MS
Corn (grain)	1.7	12	MS
Cotton	7.7	5	T
Grapefruit	1.8	16	S
Lettuce	1.3	13	MS
Onion	1.2	16	S
Potato	1.7	12	MS
Rice	3.0	12	MS
Soybean	1.7	20	MT
Sugar beet	7.0	6	T
Tomato	2.5	10	MS
Wheat	6.0	7	MT
Wheatgrass, tall	8.5	4	T

1/ Salinity is expressed as electrical conductivity of the soil solution. The standard units are millimhos (mmhos) per centimeter (cm) at 25 degrees Celsius.

2/ Yield decreases are expressed as a percentage of full unaffected yield.

3/ S = sensitive; T = tolerant; M = moderate. Ratings for some tree crops are based on growth rates rather than yield responses because of limited data.

Sources: (15, 28).

(off the farm) are often substantially greater than onsite productivity losses.

Agricultural, municipal, and industrial water uses are affected by salt pollution. Drinking water may be contaminated. Salt corrodes household and industrial equipment, shortening its life and accelerating replacement. Cleaning and processing costs climb. Sports fisheries and other wildlife habitat may also be harmed (12).

Other farms downstream use water that has collected salts from acreage upstream. This increases saline concentrations and subsequent damage to agricultural productivity.

Potential Acreage Available--Saline Land

How widespread a problem is saline soil? Approximately 10 percent of total U.S. crop and pasture land is affected to some degree by salinity according to USDA estimates (28). Agricultural lands are defined as saline when electrical conductivity of soil moisture exceeds 2 millimhos per centimeter. Approximately 26 percent of saline lands are irrigated.

The second appraisal under the Resources Conservation Act (RCA), prepared by USDA, reports the extent and location of U.S. crop and pasture lands affected by salinity (28). Acreage estimates were obtained by cross-referencing information in the National Cooperative Soil Survey (NCSS) and the 1982 National Resources Inventory (NRI) (29).

While salt exists in trace amounts throughout the United States, saline soils predominate in the arid Western States where low precipitation levels slow the natural leaching of soil salts. Highest concentrations of salt-affected croplands are in irrigated areas of the Southwest and in dryland areas of the Northern Plains (28).

Our analysis focuses on the most seriously affected, highly saline, irrigated soils. Soils are defined as highly saline where electrical conductivity of soil moisture exceeds 8 millimhos per centimeter. Salinity concentrations on highly saline soils are sufficient to reduce yields of most irrigated crops. In addition, saline drainage flows from irrigated soils may contribute significantly to offsite water-quality problems.

Saline Acreage Potentially Eligible for CRP Enrollment

This section identifies about 4 million irrigated, highly saline acres which could be targeted by the CRP. Figure 1 shows the distribution of irrigated lands with highly saline soils using the U.S. Department of Interior's Aggregated Subarea (ASA) designations. Highly saline, irrigated soils occur throughout the Southwest and Mountain States, with highest concentrations in southern Colorado, Nevada, and central California (28).

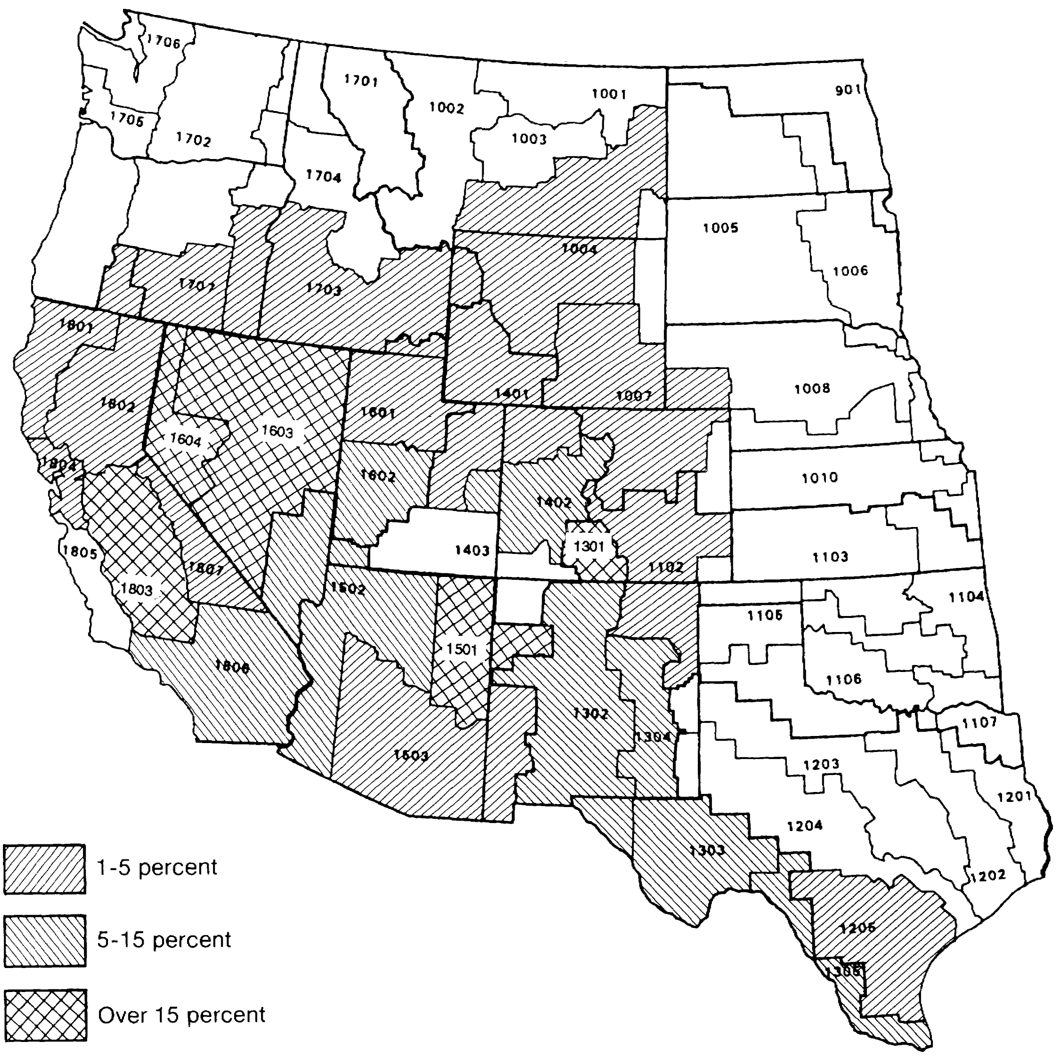
Acreage in highly saline, irrigated soils is small relative to total acreage currently eligible for the CRP (70 million) (28, 31). County enrollment ceilings and crop enrollment restrictions limit potential new enrollment of irrigated, saline croplands. Further, some saline lands that are erodible will not be in the pool of potential new acreage because they are already eligible for the CRP.

A substantial portion of farmland in salt-affected areas is ineligible due to historical cropping patterns. Annual crops and hay crops in rotation may qualify for enrollment. Continuous hay, pasture, and orchards are not eligible. Alfalfa and other hay acreage account for 35 percent of cropland in ASA's with high concentrations of irrigated, saline soils, and exceeds 50 percent in areas of Colorado, Utah, Wyoming, and Oregon (30). Presumably most of this hay is grown continuously and is not eligible for the CRP. Fruit and nut production is significant in salt-affected areas of California, Arizona, and Texas, so much of the cropland in these areas is ineligible for the CRP (34).

Acreage ceilings on CRP enrollment limit the number of salt-affected acres available. Only 25 percent of total cropland in a county may be idled under the CRP, to minimize secondary effects of land retirement on local economies. Ceilings may be exceeded in certain cases at the Secretary of Agriculture's

Figure 1

Aggregated subareas with highly saline, irrigated soils as a percentage of all cropland



Source: (28).

discretion (27). In certain counties within Colorado, Utah, Texas, and Idaho, where enrollment already exceeds 10 percent of total cropland, expansion of the program to capture saline lands is limited. However, the majority of highly saline, irrigated soils are located in areas with low CRP participation rates (28, 30).

A small amount of irrigated, saline cropland is now eligible for CRP enrollment based on existing criteria for highly erodible soils and stream buffers (30). However, currently enrolled CRP cropland does not include much irrigated land. Approximately 400,000 acres of CRP-enrolled cropland were irrigated through 1987, accounting for less than 3 percent of enrolled acreage in the Western States (21). Most of this acreage is in ground water pumping areas overlying the Ogallala aquifer in the Southern and Northern Plains. Enrollment of irrigated acreage in States with significant irrigated, saline soils (Colorado, Utah, Wyoming, Arizona, New Mexico, and California) is small both in absolute terms and as a percentage of total cropland (21).

Salt-tolerant small grains and cotton are the farm program commodities that would be most affected if saline lands could go into the reserve. Small grains account for nearly 37 percent of cropland in ASA's with high concentrations of irrigated saline soils. Small grains predominate in salt-affected areas of Colorado, Nevada, Idaho, and northeastern California. Cotton, accounting for about 21 percent of acreage, is grown in salt-affected areas of Texas, New Mexico, Arizona, and California. Corn accounts for only 6 percent of total acreage, while acreage in rice, soybeans, sorghum, and oats is negligible (28, 30).

Benefits of Retiring Saline Land

Major environmental benefits can be expected if highly saline, irrigated lands are retired from production. Data specific to the Colorado River Basin were used for the estimation. We also discuss whether the results for the Colorado River Basin apply to other river basins of the West.

Upper Colorado River Basin Case Study

The Colorado River Basin was selected for a case study because (1) physical and economic data on salinity are available and (2) saline acreage in eligible crops is significant.

Agriculture in the Upper Colorado Basin region contributes to salt buildup in the river through salt-loading and salt-concentrating effects of irrigation. Water users in the Lower Colorado Basin pay the costs of pollution that enters in the upper portion of the river.

Total damages from salinity in the Lower Colorado River Basin are between $310.8 million and $831.1 million per year (table 2). Household water users downstream bear the greatest costs. Agriculture is relatively less sensitive than other sectors to increases in salinity. Annual damage from salt concentration in the Lower Colorado is between $600,000 and $1.6 million for each additional increment (milligram per liter or mg/L) of salt in the water (table 2). This suggests that about a 30 percent reduction in salinity results in a damage reduction of $0.6 million per mg/L salt, while an additional 20 percent reduction results in an additional $1 million per mg/L salt reduction. Larger reductions thus have a proportionally greater impact on salt damages.

Offsite costs per ton of salt added in the Upper Colorado Basin are shown in table 3. The estimated salt loading rate used for this analysis is 2 tons per acre (36). For every 10,000 tons of salt entering the upper part of the river, salt concentration downstream rises about 1 milligram per liter, according to the U.S. Department of the Interior (12). Each ton of salt is thus linked to $160 in costs downstream, including $60 for agriculture.

On an acreage basis, the annual benefits of retiring highly saline, irrigated land from production are about $320 per acre, including $120 for agriculture.

Net benefits of adding irrigated, saline land to the CRP clearly exceed the environmental benefits of retiring the erodible lands that are now eligible for the reserve. The erodible soils that are now in the CRP yield about $10 per acre in offsite environmental benefits (19).

Estimates presented here may understate actual benefits to the Colorado River Basin. Our approximations are conservative for the most serious salt problem areas, where annual salt loadings may exceed 10 tons per acre rather than the 2 tons we assumed (32). The concentration of salt sources on a relatively small cropped area suggests one of the advantages of the CRP: It can be targeted to major sources of salt pollution. Our benefit estimates also

Table 2--Salinity damages in the Lower Colorado River Basin

Water use	Damage range 1/		
	$ million		
Agriculture	112.8	-	122.5
Household	156.1	-	637.6
Utility	3.2	-	22.8
Industry	6.1	-	15.8
Policy-related 2/	32.6	-	32.6
Total	310.8	-	831.1

1/ Cost estimates are based on salinity damages under "current" saline levels relative to reduced "baseline" levels for the Colorado River. Current levels reflect a 10-year average of saline concentrations at three gauging stations: Hoover Dam (652 mg/L TDS), Parker Dam (678 mg/L TDS) and Imperial Dam (767 mg/L TDS). Alternative baseline levels include 1) saline concentrations attributable to natural point and diffuse sources at Hoover Dam (334 mg/L TDS) and 2) threshold levels under the EPA Secondary Drinking Water Standard (500 mg/L TDS). Alternative baseline levels define the range of costs provided above.

2/ Policy-related damages reflect additional costs required to meet water-quality regulations in southern California, Orange and Riverside counties. These include annual capital costs of $7.9 million and annual operation and maintenance costs of $24.6 million for water treatment and conveyance facilities.

Source: (13).

Table 3--Costs from salinity per acre of cropland contribution salt: The Upper Colorado River Basin

Item	Damages	
	Agriculture	All uses
	Dollars	
Costs of each additional milligram per liter of salt, Lower Basin 1/	600,000	1,600,000
Costs per ton of salt loaded, Upper Basin 2/	60	160
Costs per salt-contributing acre, Upper Basin 3/	120	320

1/ Baseline costs for EPA threshold level (table 2, lower bound) converted to costs per mg/L TDS, using a representative current TDS level of 700 mg/L. Damages per mg/L TDS = damages / (700 mg/L - 500 mg/L).
2/ Costs per mg/L TDS converted to costs per ton of salt loaded. One ton of salt loaded (Upper Basin) = 0.0001 mg/liter increase in salt concentration (Lower Basin).
3/ Based on an estimated 2 tons loaded per acre (36).

Source: (12, 13).

exclude cost savings of reduced desalination required to meet water quality obligations to Mexico (36).

These estimates do not reflect opportunity costs of water in relatively low valued agricultural uses. If irrigation water saved by idling land were allowed to move to higher value, nonagricultural uses, major economic benefits could result. Studies identify important gains from additional water supplies to power generation and other private industries (5, 6, 40).3/ Whether water saved in agriculture is actually available for higher valued uses remains a complex issue for future analysis.

Making precise calculations of water-quality gains is difficult. Researchers make assumptions on various technical features of the land and water, and on economic issues such as demand for water downstream. Hydrologic systems are complex and do not fit easily into models created by analysts.

3/ For example, benefits resulting from increased hydroelectric energy generation alone are valued at $25 per acre annually in the Colorado River Basin (7). In California's San Joaquin Valley, potential savings from permanently transferring water from cropland that contributes selenium to the Kesterson Wildlife Refuge to State uses are $4,511 per acre idled (40). However, transfers of water to higher valued uses in the West would require changes in water rights laws.

Because we are examining nonpoint-source pollution, we cannot be sure how much retiring a particular piece of land will help control the pollution. Researchers have not resolved fully questions about spatial and temporal distribution of salinity effects, and how much salt in water can be tolerated by certain types of water use.

Despite the questions remaining, the magnitude of damage from salt in the Colorado River suggests that moving irrigated croplands near the Upper Colorado River into the CRP yields significant environmental benefits. Retiring saline croplands may be more cost-effective than other pollution control methods under consideration for southwestern Colorado (6).

Applicability of Colorado River Case to Other Areas

The Colorado Basin has several unique features that contribute to high saline concentrations. Thus, the benefits of controlling saline pollution in the Upper Colorado Basin are apt to be greater than those expected for other areas of the West.

Saline subsoils underlie much of the cropland in the Upper Colorado Basin. Irrigation drainage in contact with natural saline formations causes unusually high salt discharges into waterways. Drainage through saline subsoils is the primary source of agricultural salt contamination in Colorado's Grand Valley (6).

Irrigation efficiencies are relatively low in the Upper Colorado (33). Low irrigation efficiency results in excessive water loss through evaporation, runoff from fields, and deep percolation below the root zone. Increased drainage results in greater salt contamination of streams and rivers.

Irrigation drainage in the Upper Colorado Basin generally reenters the Colorado River through surface drainage channels and subsurface flows, thereby contributing directly to downstream water quality problems. In other areas of the West, as in California's San Joaquin and Imperial Valleys, drainage may be channeled to evaporating ponds and larger drainage sumps. Because salts are not directly discharged in rivers, effects on downstream users are negligible. But these systems may cause other local environmental problems, including impaired wildlife habitat and ground water contamination (40).

High evaporation losses within the Colorado Basin contribute to increasingly high salt concentrations downstream. High evaporation losses reflect the length of river flow, dam storage, irrigation diversions, and arid climatic conditions in the region. Because other river basins in the West have lower evaporation losses, damages from salt loadings may be less than for the Colorado example.

Finally, municipal and industrial users draw heavily from the Colorado River, and diversions for nonagricultural uses are likely to increase (13). Demand for clean water in high value uses increases the economic benefits of improved water quality. In other river basins where there are fewer municipal and industrial demands, economic benefits may be less than for the Colorado example.

Costs of Retiring Saline Land

Net returns per acre of irrigated cropland in highly saline soil are high, so costs of enrolling these acres in the CRP are substantial. Program costs to retire saline land are based on data for wheat, since wheat is an important crop grown in salt-affected areas.

Yield and net return estimates were based on 1982 national budget data for dryland and irrigated cropland in 105 Production Areas (PA's) and 6 land groups (11).4/ Yields and commodity prices were adjusted to the 1982 crop-year.5/ Net returns for highly saline, irrigated soils were assumed equivalent to average irrigated returns in salt problem areas. Net returns may actually be somewhat lower on the most critical saline acres due to additional treatment costs.

Table 4 identifies net returns per bushel of wheat produced on three land categories in 1982: 1) CRP-enrolled acreage through 1987 (30), 2) all U.S. acreage, and 3) acreage with high concentrations of irrigated, saline soils. Saline soils are found in ASA's 1301, 1603, 1703, and 1803, which contain over a million highly saline, irrigated acres (fig. 1).

Net returns were high on irrigated, saline acres planted to wheat. Average wheat yields in salt-affected regions exceeded the U.S. average by nearly a factor of three in 1982. High net returns reflect high irrigated yields and the relatively low (often federally subsidized) costs of surface water.

In order to reduce pollution, water rights must be reduced proportional to acreage idled (or rented with the land). Assuming water rights are rented, the 1982 costs for idling irrigated, saline soils in the CRP are high. Even if CRP rules were adjusted to target the least productive saline acreage, retirement costs would greatly exceed the 94 cents per bushel of production that would have been forgone if the CRP idled average soils, as well as the 53 cents per bushel net return on CRP-enrolled acreage (table 4).

Irrigated Land in Ground Water Depletion Areas

Salt pollution is not the only environmental threat linked to irrigated farming. In many areas of the West, ground water supplies are depleted by irrigation, causing the water table to fall. Ground water decline may result in higher pumping costs, land subsidence (settling), and salt water intrusion into aquifers.

4/ PA's are roughly equivalent to ASA's.

5/ After 1982, program target prices changed relatively little while market prices fell, making somewhat uncertain the relative influence either price had on farmers' production decisions. Similarity between target prices and market prices in 1982 facilitates economic analysis. This was the last year in which target prices and market prices were nearly the same so we assume that production decisions were not influenced by target prices.

Potential Acreage Available--Ground Water Depletion Areas

Half of the 30 million acres irrigated with ground water in the West contribute to water table decline (22). On the Texas High Plains, water tables have at times fallen by up to several feet per year. Other major problem areas include southern Arizona and central California (22).

Cotton is the crop most commonly planted in ground water depletion areas. Virtually all CRP acreage that was formerly planted to cotton is in the Southern Plains (30).

Little opportunity exists to add acreage to the CRP in ground water decline areas. Existing CRP regulations prevent much of these lands from being added to the reserve. Most of the counties experiencing severe ground water declines in the Southern Plains are at or near the 25-percent enrollment limit mandated in the Food Security Act of 1985 (30). The following analysis focuses on the costs and benefits of enrolling irrigated croplands in remaining critical ground water decline areas, located in southern Arizona and central California.

Benefits of Retiring Land in Ground Water Depletion Areas

Offsite environmental benefits from enrolling irrigated acreage in ground water decline areas are too small to justify targeting their enrollment in the CRP. The primary economic gains involve offsite pumping cost savings with reduced ground water drawdown. Some smaller benefits are expected from reduced salt water intrusion into aquifers. Annual offsite benefits are less than half the current $10 per acre water-quality benefits for erodible land enrolled in the CRP as of the fifth signup (1, 19).

Table 4--Yield and net returns for wheat acreage enrolled in CRP, average U.S. wheat acreage, and highly saline wheat acreage 1/

Land type	Yield	Net returns	
	Bushels/acre	Dollars/acre	Dollars/bushel
CRP wheat acreage	32	17	0.53
Average U.S. wheat acreage	36	34	.94
Highly saline wheat acreage 2/	106	261	2.46

1/ Prices, costs, and yields are for 1982. "Net returns" refers to gross receipts from sales, minus all costs other than land rent and management. Disaster relief payments are not included in net return estimates (11).
2/ Acres located in PA's 87, 90, 94, and 101, which each contain 100,000-1,000,000 acres of highly saline soils. These PA's, which are roughly equivalent to ASA's 1301, 1603, 1703, and 1803, are located in central California, Nevada, southwestern Wyoming, and southern Colorado (fig. 1) (29).

Costs of Retiring Land in Ground Water Depletion Areas

Because of the high returns to irrigated farming, using the CRP to reduce ground water decline would be a high-cost effort. Irrigated cropland in remaining areas potentially eligible for a reserve program to conserve ground water is very profitable in its current agricultural use. Acreage in Arizona and California yields positive net returns far above the benefits to be expected from retiring the land.

Cotton data were used to assess the costs of idling land in ground water depletion areas (table 5). Net returns per bale of cotton in 1982 ($100/bale) were three times higher in the California and Arizona ground water depletion areas than in the United States as a whole. The Southern Plains area had a different financial picture. Net returns were low or negative, primarily because of poor weather (16). Ground water depletion is a concern in the Southern Plains, but much of the nonirrigated land there is already enrolled in the CRP to the maximum level allowed by law.

Highly Erodible Land Targeted To Reduce Sediment and Nutrient Pollution

Setting aside additional highly erodible land can cut phosphorus and nitrogen pollution in lakes and estuaries, if areas with the greatest potential water-quality benefits are targeted. Idling erodible lands prevents runoff of soil carrying these nutrients. High nutrient levels in water can cause eutrophication, a process that encourages excess plant growth in water, to the detriment of desirable fish species and recreation opportunities.

Table 5--Yield and net returns for cotton acreage enrolled in CRP, average U.S. cotton acreage, and cotton acreage in ground water depletion areas 1/

Land type	Yield	Net returns	
	Bales/acre	Dollars/acre	Dollars/bale
CRP cotton acreage	0.64	0	0
Average U.S. cotton acreage	1.22	4	33
Cotton acreage in ground water depletion areas 2/	2.91	291	100

1/ Prices, costs, and yields are for 1982, which are well above current world prices but below support prices. "Net returns" are the gross receipts from sales, minus all costs other than land rents and management (11). Disaster relief subsidies are not included in net return estimates.

2/ Since CRP enrollment is near the 25-percent county cropland enrollment limit in many High Plains counties, this analysis focuses on the remaining ground water decline acreage in central California and southern Arizona (ASA's 1803 and 1503) (16).

Potential Acreage Available--Erodible Land

Erodible land from many locations in the country could be targeted for enrollment in a CRP targeted to improve water quality. The location of the priority areas depends on the specific water-quality goal desired.

Regions affected by agricultural pollutants were identified using data from the National Stream Quality Assessment Network (NASQUAN), U.S. Geological Survey (20). Data from 1982 and 1983 from 470 monitoring stations were used to estimate concentrations of phosphorus, Kjeldahl nitrogen, and suspended sediment in each of the 99 ASA's in the lower 48 States.

Five different water-quality threshold criteria were identified (table 6). Each reflects a different assumption regarding the concentrations of pollutants likely to harm selected aquatic environments. Criteria 1 and 2 apply to rivers (41).

Criteria 3, 4, and 5 apply to lakes and estuaries. Because pollutants build up in lakes and estuaries, the threshold levels are lower than those for continuously flowing rivers (39). Freshwater lakes are sensitive to phosphorus, while salt water estuaries are sensitive to nitrogen.

Controlling pollution from cropland may not solve water-quality problems in areas with serious nonagricultural pollution problems. To determine whether adding farmland to the CRP would improve water quality, we first estimated

Table 6--Water-quality threshold criteria 1/

Item	Phosphorus	Kjeldahl nitrogen	Suspended sediment
		Milligrams per liter	
Rivers:			
Criterion 1	0.1	0.9	90
Criterion 2	.2	2.0	200
Lakes:			
Criterion 3	.01	--	--
Criterion 4	.05	--	--
Criterion 5	.10	--	--
Estuaries:			
Criterion 3	--	.09	--
Criterion 4	--	.45	--
Criterion 5	--	.90	--

-- = Not applicable.
1/ Estimates represent the upper limit for each threshold.

Sources: (39, 41).

the share of an area's contaminants originating on cropland. We used data from Resources for the Future's Pollutant Discharge Inventory (19).

We then estimated the percentage decrease in concentration needed to meet our water-quality threshold in each ASA with at least one pollutant above the threshold. If the percentage decrease required for each pollutant above the threshold was less than or equal to the percentage of total contributed by agriculture, it was assumed that reducing cropland's share would improve water quality. These were the regions targeted for the CRP.

Priority Areas for River Improvement

Regions that are priority candidates for improving water quality in rivers, using criteria 1 and 2, are shown in figure 2. Most of these ASA's are in major sheet and rill erosion areas in the Corn Belt and elsewhere across the United States.

If the CRP were implemented using the criteria that apply to lakes and estuaries, the priority areas for pollution control would be different (fig. 3). Phosphorus and nitrogen reductions sufficient to improve lake and estuary water quality under criterion 5 can be accomplished through land retirement in the major feed grain producing areas, and the Gulf and southern Atlantic coasts. These areas roughly correspond with the areas that suffer from the highest levels of soil erosion from rainfall, the corn- and soybean-producing regions (29).

When a higher water-quality level for lakes is desired, the phosphorus threshold is reduced by half (criterion 4). Under this standard, the scope of the program expands so that regions known more for lakes and estuaries than for field crop production become eligible. The geographic regions covered include much of Wisconsin, Michigan, Georgia, and eastern New York and Pennsylvania (fig. 3).

Areas in the Northeast and Delta regions of the United States offer the best opportunity for targeting additional erodible land for lake and estuary water quality (table 7). In many of these Eastern ASA's, less than 5 percent of eligible land has been enrolled in the CRP. Water quality protection is possible under threshold criteria 4 and 5 for lakes and estuaries (fig. 3). No regions could reduce their water pollution enough to meet criterion 3 through cropland retirement.

Benefits of Retiring Erodible Land in Priority Areas

The benefits from targeting regions with sediment-related nutrient problems are evident when we compare regional benefit estimates for the first five CRP signups in table 7. These estimates of regional CRP benefits during its first 2 years emphasize the advantage of targeting areas with serious nutrient damage associated with soil erosion. The highest benefits to date have also occurred in areas like the Northeast and the Pacific Northwest where the demands for clean water are the greatest.

Costs of Retiring Erodible Land in Priority Areas

Costs of targeting these predominantly corn-producing regions are much harder to estimate than the costs of the relatively modest program modifications required for addressing salt pollution and ground water drawdown. The

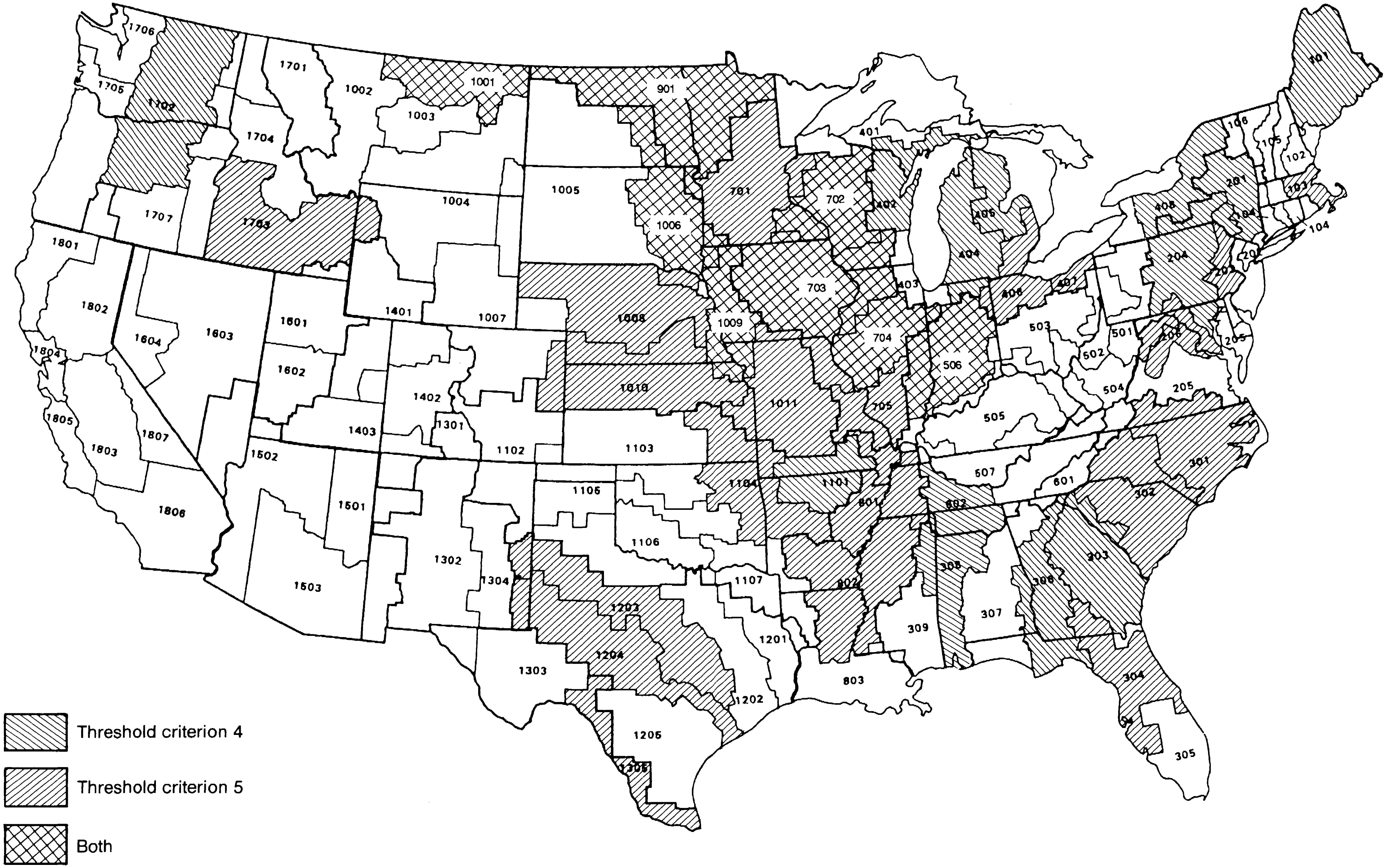
Figure 2

ASA's where erosion control will most affect water quality of rivers

Source: (41).

Figure 3

ASA's where erosion control will most affect water quality of lakes and estuaries



Source: (39).

difficulty stems from the predominance of corn and soybeans grown in regions suffering from nutrient pollution.

Wheat and cotton are the main eligible crops in the West, in contrast to corn and soybeans, which dominate agriculture in the areas targeted to address phosphorous and nitrogen pollution of surface water. Although corn and soybean acres have been renting for twice the rent per acre for Western regions, idling land in these two crops reduces USDA outlays for feed grain programs. Thus, the net effect on Government outlays of changing the crop mix of CRP land is harder to predict.

Stream Buffer Zones

Analysis will show that retiring 100-foot buffer strips also yields significant environmental benefits and at reasonable cost per acre. Effects on enrollment patterns would be minimal since few acres are available in the stream buffer category.

Setting aside buffer strips along lakes or streams cuts sediment and nutrient discharges into water. Permanent vegetation slows runoff flow, so transported material is deposited on the land instead of flowing into water.

Table 7--Present value of water-quality benefits for first five signups of the CRP, by region 1/

Region	Estimated benefits		
	Best 2/	Range	Per acre
	---- Million dollars ----		Dollars
Appalachia	137	80-195	180.5
Corn Belt	267	148-386	81.6
Delta States	218	134-308	321.1
Lake States	255	146-362	128.5
Mountain States	326	177-477	67.0
Northeast	29	17-41	267.7
Northern Plains	215	114-323	41.2
Pacific	185	103-273	126.1
Southeast	174	104-249	176.1
Southern Plains	241	128-356	65.8
Total	2,047	1,151-2,970	89.0

1/ Estimated benefits are for the CRP contract period, based on 23 million acres enrolled in the first five signups.
2/ Best estimate is the most likely extent of offsite benefit.

Source: (19).

Stream buffers effectively reduce delivery of sediments from forests, pastures, cropland, and all other nonpoint sources of pollution in the watershed. The effectiveness of buffers depends on velocity and depth of runoff, topography of the land, width of the strip, and condition of the plant cover.

Potential Acreage Available--Stream Buffers

About 3 million acres were estimated to be eligible for the CRP under the new stream buffer category. Using the Environmental Protection Agency's River Reach file, we estimated the total length of streams within each ASA. Then we calculated the cropland lying within 100 feet of each stream bank in the ASA.

We made several assumptions in deriving the figures on acreage potentially eligible for the CRP. We assumed that the percentage of riparian land used for cropland equals the percentage of all acreage in the ASA used for cropland.

From this total acreage of riparian cropland, we subtracted a percentage of land that already would have been eligible for the CRP under its original erosion criteria. We assumed that the percentage of riparian cropland eligible for the CRP on the basis of erosion criteria equals the percentage of all ASA cropland eligible for the CRP. What remains are about 3 million acres near water that can be added to the reserve under the new environmental criteria for stream buffer zones.

Benefits of Retiring Stream Buffers

Calculating a monetary value was the next step (table 8). The estimates here followed the methodology of earlier USDA estimates on water-quality benefits of reduced erosion (19). Benefits include reduced cost of water treatment, sediment removal, reservoir siltation, flood damage, and damage to appliances and equipment that use water. There are also benefits from increased recreational fishing. A discussion of the procedures used to estimate benefits is presented in the Appendix.

Buffer strips on average cut suspended sediment loadings and runoff by about 25 percent and nutrient loadings by roughly 25-50 percent (2). The larger reductions in nutrient loads are not unusual, but runoff from steeper fields may become a concentrated flow which plows right through buffer strips. In such cases other practices will be needed. Although most U.S. cropland falls in the former, less steep category, the analysis here used the more conservative, average reduction figure for buffers of 25 percent.

We assumed that the percentage of an ASA's total runoff which passes over a buffer strip equals the percentage of ASA stream miles lined by buffers. Permanent vegetation along waterways would thus substantially cut sediment and nutrient delivery.

Annual benefits of stream buffer strips averaged $68 per acre. This is well above the $10 per acre of water-quality benefits gained by retiring erodible land under original CRP rules. Assuming not all 3 million acres of buffers can be enrolled, gains per acre could be maximized by targeting highest priority areas for installing buffers.

Some sources of stream pollution have escaped this analysis. Sediment and nutrients that enter waterways via ditches that are not eligible for CRP buffers were not covered in our estimates.

Neither does this report quantify benefits of installing buffer zones around lakes. How lakes respond to cleanup efforts depends on lake size, depth, temperature, and location (39). Proximity to fields and streams within the watershed influences pollutants delivered to lakes. These factors cause benefits of lake buffers to vary greatly, so more research is needed before costs and benefits can be analyzed.

Costs of Retiring Stream Buffers

Little is known about the distribution of land groups near streams, so estimating costs of enrolling buffers in the CRP is difficult. We assume that cropland eligible under the buffer provision represents a cross-section of U.S. cropland, and that costs would differ little from current program costs, which are around $70 per acre in the major corn- and soybean-producing regions (16).

Cropped Wetlands

Making cropped wetlands eligible for the CRP yields environmental benefits. Some of the cropped wetland can be enhanced and provide valuable breeding habitat and wintering grounds for migratory waterfowl and other wildlife.

Table 8--Benefits of retiring stream buffers 1/

Region	Acreage	Benefits	
	Thousands	Million dollars	Dollars per acre
Appalachia	227	17.7	78.3
Corn Belt	679	29.8	43.9
Delta States	226	15.2	67.3
Lake States	366	18.6	50.8
Mountain States	234	30.6	30.8
Northeast	106	6.5	61.9
Northern Plains	535	12.0	22.5
Pacific	146	43.6	298.3
Southeast	146	7.0	48.0
Southern Plains	232	14.9	64.4
Total	2,894	195.9	67.7

1/ These estimates are for lands within 100 feet of streams not previously eligible for the CRP. The buffers are expected to reduce sediment and nutrient delivery by 25 percent, and no concurrent reductions in erosion on the field are assumed to exist.

Wetlands also help maintain ground water aquifers and filter nutrients that might damage other waterways. Rules extended eligibility for 1989 CRP signups to about 6 million acres of cropped wetlands with high physical potential for conversion.

Potential Acreage Available--Cropped Wetlands

A portion of the cropland identified in the NRI is currently cropped wetlands, not yet adequately treated. These acres include prairie potholes that are farmed under natural conditions or are partially drained. Former hardwood swamps in the Southern United States may also be converted in many cases.

Only about 6 million acres of cropped wetlands have high physical potential for restoration. These high-potential acres make up the bulk of wet acreage that is entering the CRP.

Benefits of Retiring Cropped Wetlands

Idling cropped wetland for wildlife habitat would provide environmental benefits. Studies have not quantified the benefits of increasing freshwater wetland habitat nationwide, however. Benefits likely vary by region and depending on whether the land can be restored to its original wetland condition.

The wet acreage in the Northern Plains offers relatively high benefits per acre compared with locations further south with a climate less suitable for nesting waterfowl. Winter waterfowl habitat is also much more plentiful in

Table 9--Yield and net returns for corn acreage enrolled in CRP, average U.S. corn acreage, and cropped wetlands planted to corn 1/

Land type	Yield	Net returns	
	Bushels/acre	Dollars/acre	Dollars/bushel
CRP corn acreage	85	21	0.24
Average U.S. corn acreage	114	71	0.62
Cropped wetlands planted to corn 2/	92	7	0.08

1/ Prices, costs, and yields are for 1982. "Net returns" are gross receipts from sales, minus all costs other than land rents and management. Disaster relief subsidies are not included.

2/ The ERS budgets do not have separate budget detail for untreated wet soils. They are combined with soils having similar yields but suffering from stoniness or climatic difficulties.

the South relative to most needs. The northern wetlands thus constrain certain waterfowl populations, and are particularly valuable from an environmental and wildlife perspective.

In the Northern Plains, a field with a density of 1 wetland (or pothole) per 6 acres is eligible for the CRP. In the South, a third of the field must be wetland. These requirements have facilitated enrollment in the Northern Plains.

Costs of Retiring Cropped Wetlands

Much land with wetness problems, not adequately treated (drained), is only marginally profitable in agricultural uses. Net return estimates in table 9 indicate that this cropped wetland needing treatment is less competitive than cropland currently enrolled. This would likely be the first wet cropland to enroll.

Corn was selected for cost comparison purposes because it is an important crop in areas with significant potential for conversion back to wetland. Table 9 shows corn production and net returns (per acre and per bushel) for 1) actual CRP acreage, 2) average U.S. corn acreage, and 3) cropped wetlands planted to corn.

These relative cost differences between idling wet cropland needing treatment versus average land presumably apply to land in other crops. The absolute costs are also lower in the northern wheat regions, where land is less productive and rents for less. However, costs of converting small prairie potholes to wetlands may be much higher due to the nuisance cost of driving machinery around the potholes.

Conclusion

Few new acres would be available for enrollment under most of the environmental provisions under consideration or in early stages of implementation in the CRP.

Highly saline, irrigated lands that cause salt contamination of waterways account for only 4 million acres, many of which are planted to crops that are ineligible for the CRP. The majority of these acres are in areas with low levels of enrollment. Given the profitability of land irrigated with surface water, the cost of enrolling irrigated, saline acreage is generally prohibitive.

High profits and regulations will impede enrollment of irrigated lands in ground water depletion areas as well. Ground water decline areas account for approximately 14 million irrigated acres. Some of the worst problem acres are in Southern Plains counties, many of which are already near or beyond county CRP enrollment limits. Irrigated acreage in ground water decline areas outside the Southern Plains is so profitable that costs to enroll the land are very high.

Highly erodible land can be added to the CRP in priority areas to improve water quality. Substantial differences in water-quality benefits are evident from regional comparisons. Accepting more bids in areas with priority water-quality problems could improve water-quality gains.

Stream buffer strips offer only 3 million new acres. Environmental benefits per acre can be very significant, however, as runoff from the large areas of U.S. cropland having modest slopes can usually be filtered by idling relatively little cropland. This tool for targeting water quality can be implemented at the Federal level, and without adding much more cropland to the CRP.

Wet croplands offer low-cost acres that might help in meeting a no-net-loss of wetlands goal set by the President.

Lack of dramatic gains from implementing additional environmental provisions may reflect the limited ability of any CRP modifications to target acreage with the most severe environmental problems. Considerably larger environmental gains are within reach if State and local administrators familiar with local water-quality problems contribute leadership and support in priority problem areas.

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Appendix

The procedures used to estimate the water quality benefits from buffer strips recognized the physical, chemical, hydrologic, and economic links between the movement of soil and chemicals on the field and impacts on downstream water users.

The reductions in loadings from installing buffer strips have a direct impact on the total load of sediment and nutrients being discharged into waterways. Total discharges include those materials attached to soil particles, nutrients dissolved in the runoff, material from other nonpoint sources, and material originating from point sources, such as sewage treatment plants. Using data developed by Resources for the Future for sediment delivery, nutrients attached to sediment, and nutrients dissolved in runoff, regional changes in the discharge of suspended sediment (TSS), organic nitrogen (TKN), and phosphorus (TP) were estimated given the installation of buffers.

Reductions in the discharge of TSS, TKN, and TP will change the concentrations of those materials in receiving waters. Changes in the concentrations of these materials were estimated using water-quality models estimated at the ASA level (19). ASA's were used because watersheds are the logical unit of study for water-quality issues, and because data were available at this level of disaggregation. These models specify average concentrations of sediment or nutrients in water as a function of regional discharge of the material and volume of flow.

Several different methods were used to link changes in pollutant delivery or concentrations with the economic impacts of water-quality changes on water users. The procedure used depended on the information available about the links between erosion and offsite damages. Detailed descriptions of the methods appear in Ribaudo (19). The impacts of improved water quality on recreational fishing participation were estimated with a fishing participation model. The model was estimated with data from the 1980 National Survey of Hunting, Fishing, and Wildlife-Associated Recreation and NASQUAN. The model predicted changes in the number of fishermen and in the number of days fishermen fished in response to the regional changes in water quality. A fishing-day value of $25 was used (14).

A water treatment cost model was used to estimate the changes in municipal treatment cost from reductions in turbidity. The model specified water treatment cost as a function of turbidity, the amount of water treated, and the costs of other inputs (12). Changes in turbidity were easily estimated from changes in suspended sediment concentrations. It was assumed that water quality is a perfect substitute with turbidity-reducing inputs in the treatment process, and that the change in treatment cost does not affect the output of treated water. Benefits are therefore equal to the reduction in treatment costs (4).

Benefits to the other damage categories (navigation, flooding, municipal and industrial use, and water storage) were estimated by assuming a linear relationship between sediment discharge and damages, such that a percent reduction in discharge would generate a similar percent reduction in damages. Damages from flooding and to municipal and industrial users were obtained from Clark and others (2). Damages to navigation (in the form of dredging costs) were obtained directly from the Corps of Engineers. Damages to water storage facilities were obtained from Crowder (3).

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